Subpolar North Atlantic Ocean model biases and trends in ocean-sea ice models driven by historic atmospheric forcing

Elizabeth Maroon[1], Stephen Yeager[2], Taydra Low[1]

[1] University of Wisconsin-Madison, [2] National Center for Atmospheric Research

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What will happen to Atlantic Ocean circulation is of great interest to scientists and society...

Atlantic Ocean circulation nearing 'devastating' tipping point, study finds

Collapse in system of currents that helps regulate global climate would be at such speed that adaptation would be impossible

Sea levels in the Atlantic would rise by a metre in some regions and temperatures around the world would fluctuate far more erratically. Photograph: Henrik Egede-Lassen/Zoomedia/PA

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Collapse in system of currents that helps regulate global climate would be at such speed that adaptation would be impossible

Melting ice could create chaos in US weather and quickly overwhelm oceans, studies warn

Doyle Rice
USA TODAY

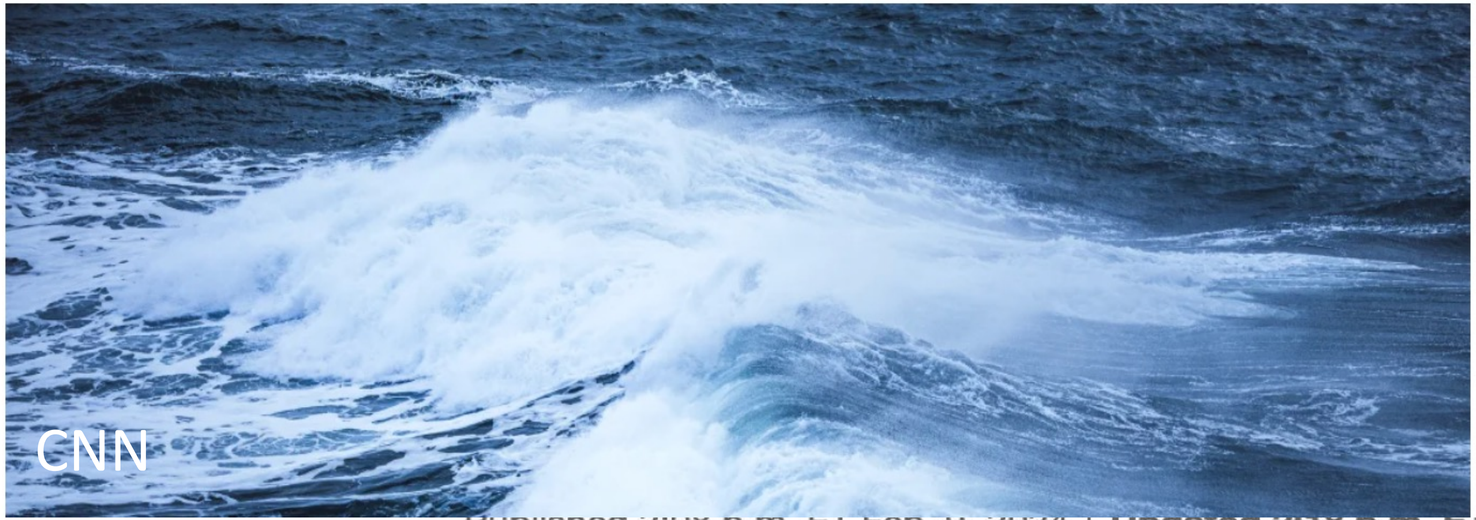
Published 2:08 p.m. ET Feb. 9, 2024 | **Updated 2:18 p.m. ET Feb. 9, 2024**

What will happen to Atlantic Ocean circulation is of great interest to scientists and society…

Critical Atlantic Ocean current system is showing early signs of collapse, prompting warning from scientists

By Laura Paddison, CNN

5 minute read · Published 2:00 PM EST, Fri February 9, 2024



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Yet, the IPCC AR6 report downgraded the confidence in historic and projected North Atlantic Ocean circulation.

IPCC Chapter 9 (Fox-Kemper et al. 2021):
"For the 20th century, there is *low confidence* in reconstructed and modelled AMOC changes because of their *low agreement* in quantitative trends. … Since AR5/SROCC, confidence in modelled and reconstructed AMOC has decreased due to new observations and model disagreement."

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Large North Atlantic Ocean upper-ocean temperature and salinity biases originate in ocean models.

Project Goals

1. Develop Process Oriented Diagnostics (PODs) for the subtropical to subpolar North Atlantic Ocean
2. Characterize biases in upper-ocean fields and thermohaline processes in Ocean Model Intercomparison Project (OMIP) simulations
3. Identify relationships between upper-ocean model biases, water mass transformation, and the Atlantic meridional overturning circulation (AMOC)

OMIP Interannual Forcing (IAF) simulations are driven by past atmospheric conditions

OMIP-1

Driving dataset: Coordinated Ocean-ice Reference Experiment (CORE, Large and Yeager 2009)

Time Period: 1948-2009

Cycles: 5

OMIP-2

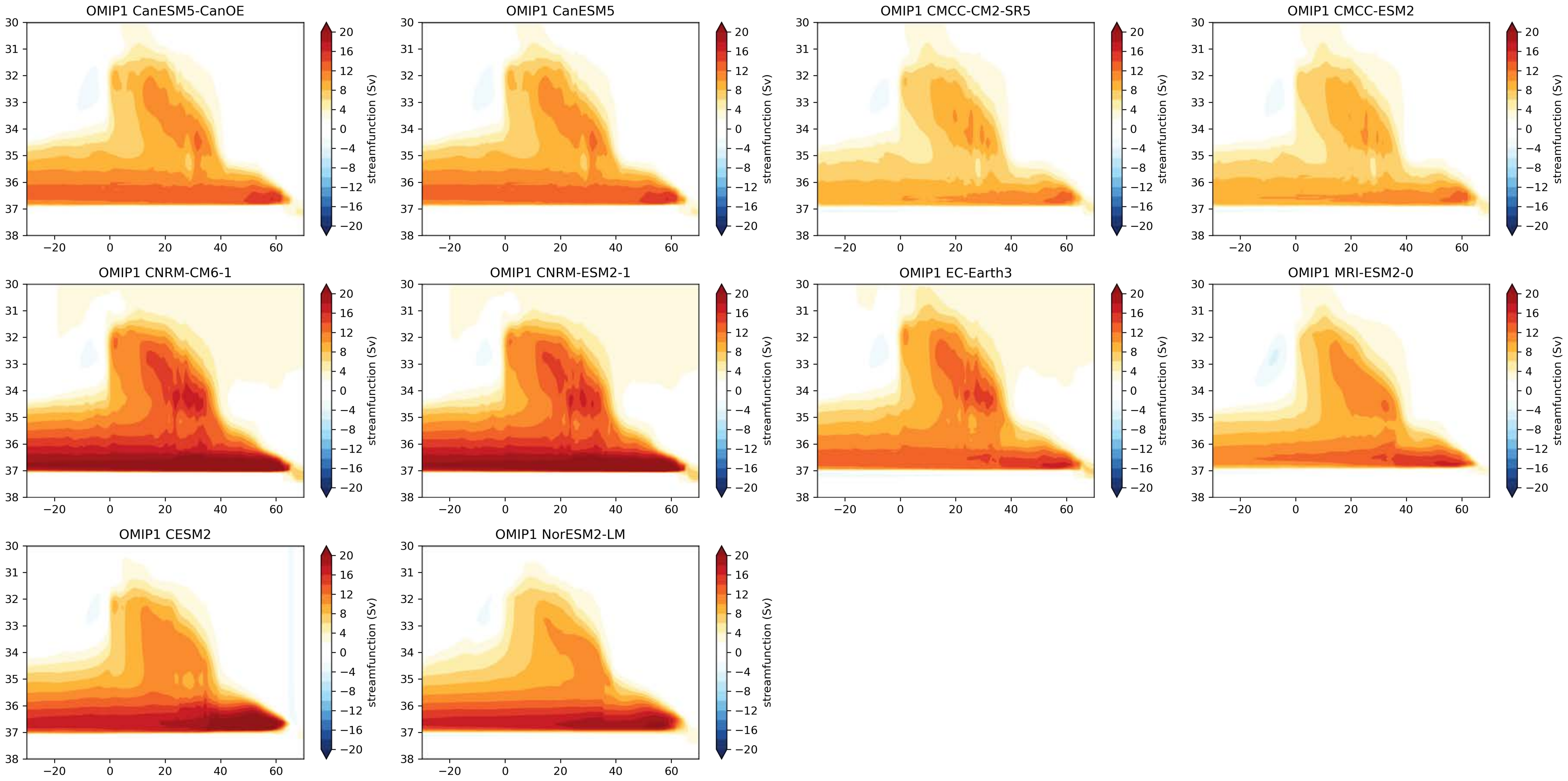
Driving dataset: Japanese 55-year atmospheric reanalysis- driving ocean (JRA55-do, Tsujino et al. 2018)

Time Period: 1958-2018

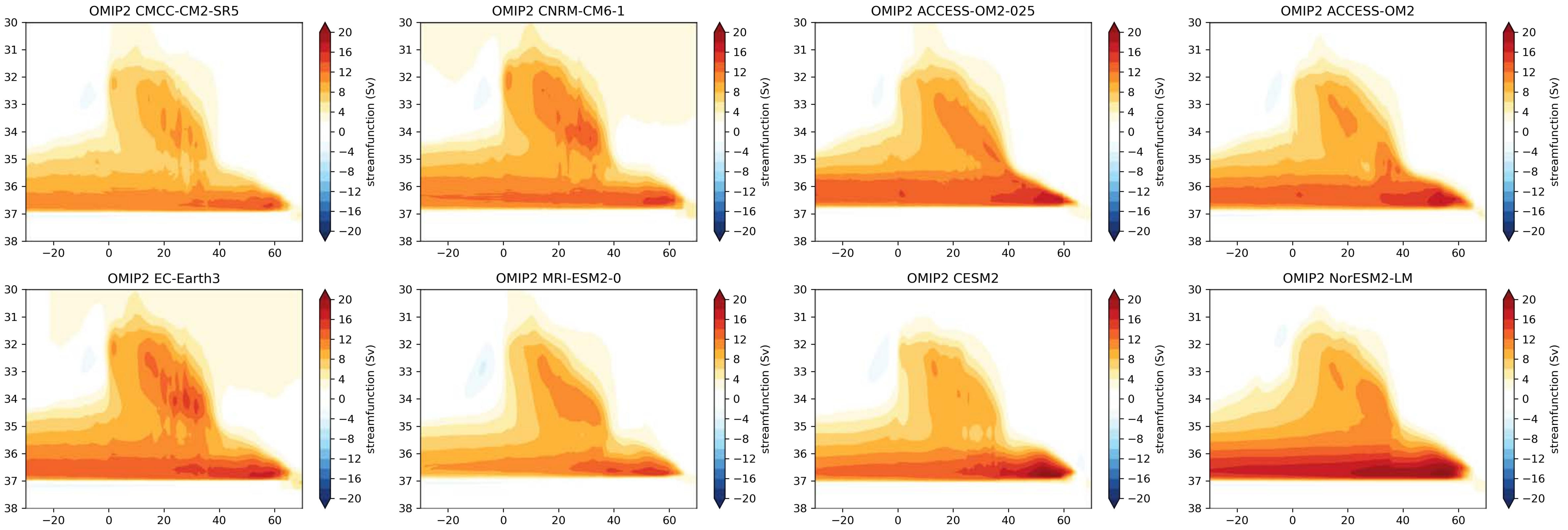
Cycles: 5-6

For a summary of the CMIP6-OMIP protocol and results: *Griffies et al. (2016)* and *Tsujino et al. (2020)*

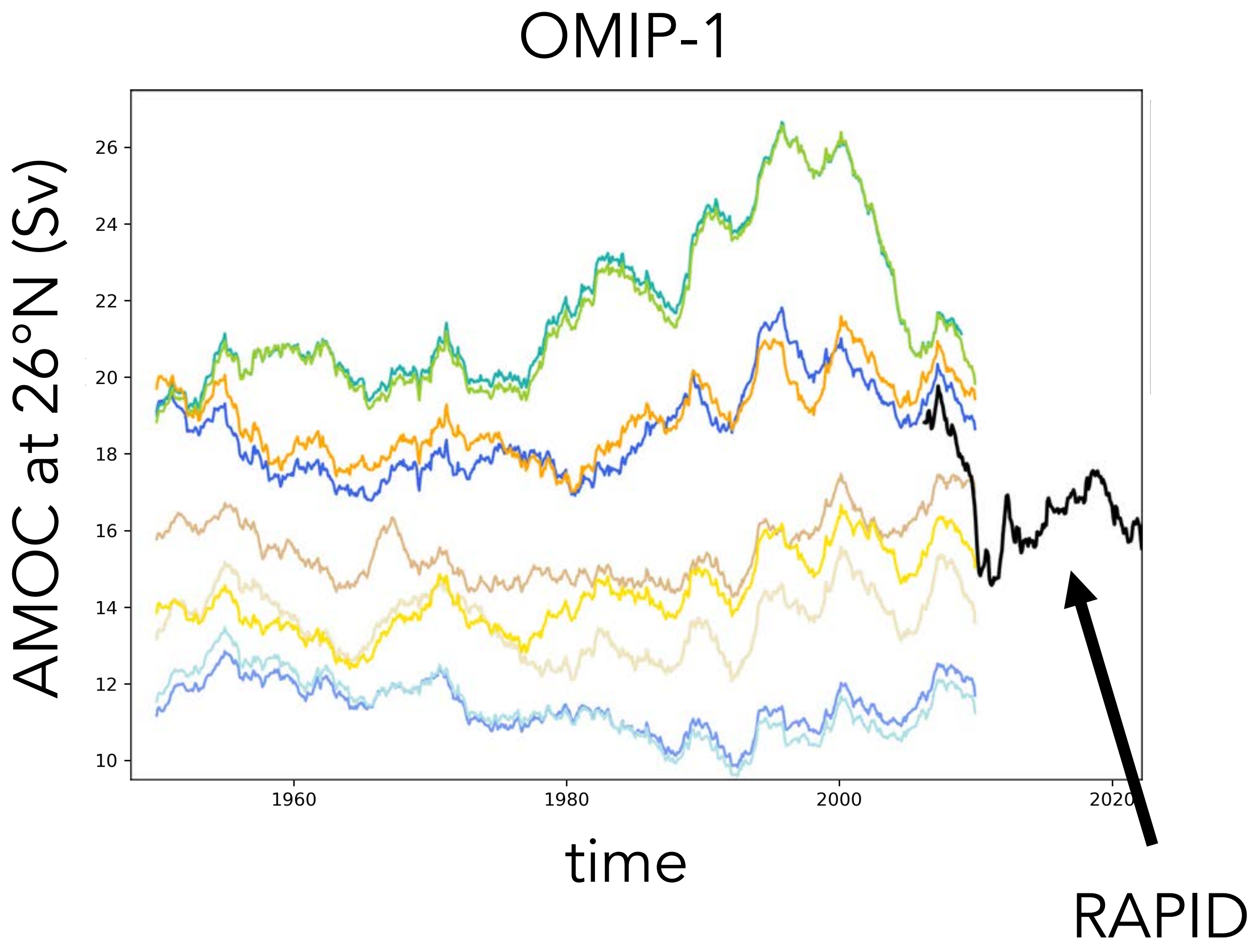
Wide range of AMOC strengths in OMIP-1

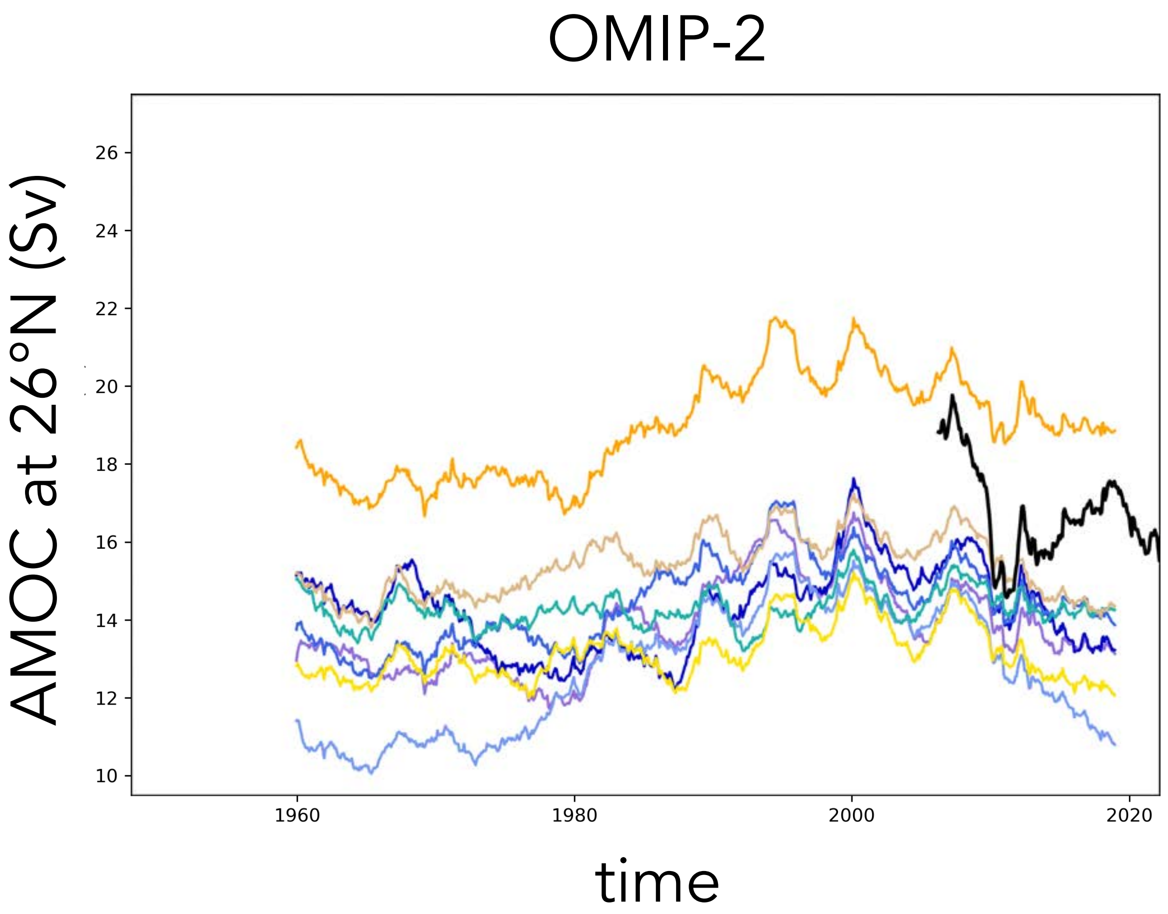


Greater AMOC agreement in OMIP-2

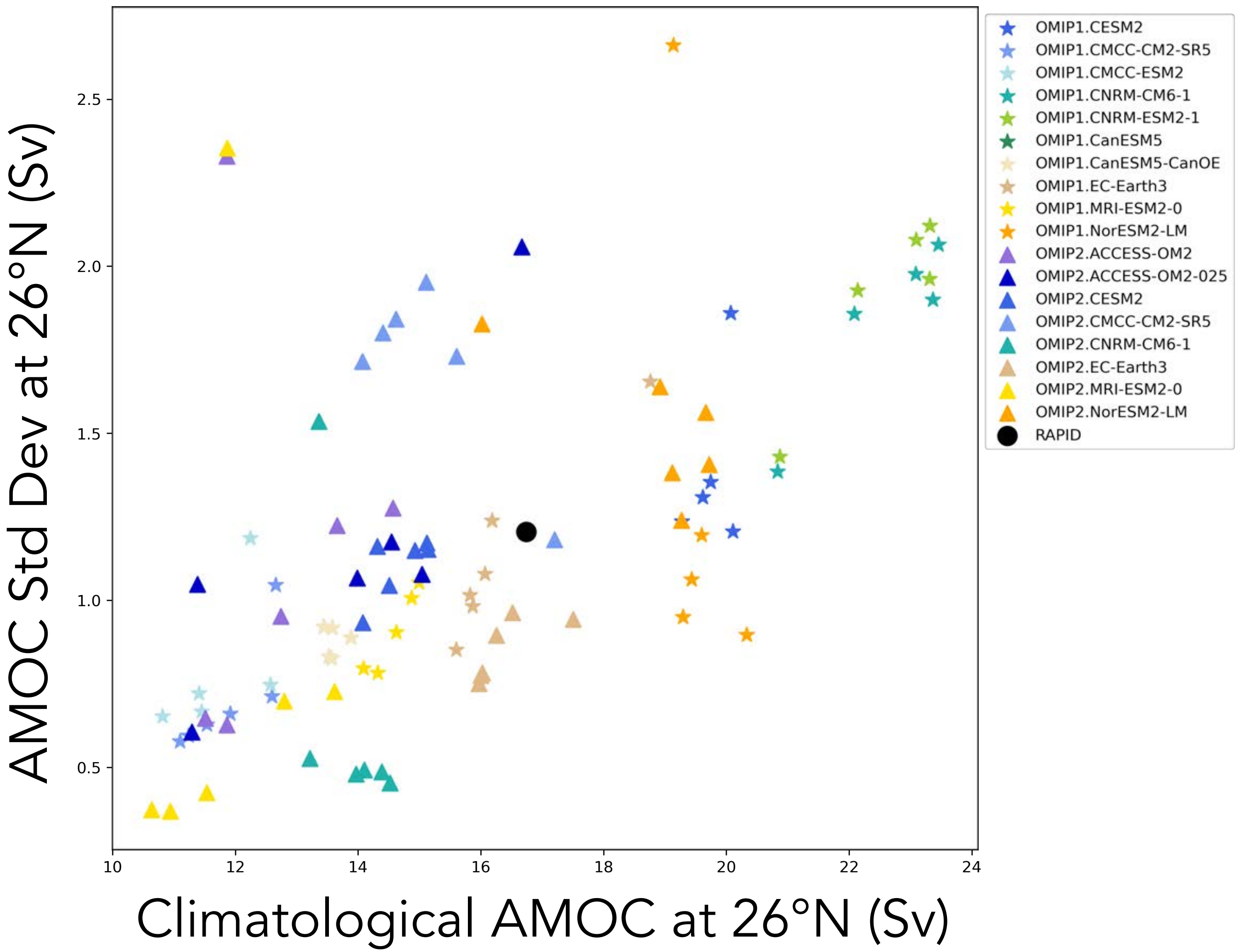


Association of AMOC strength with variability

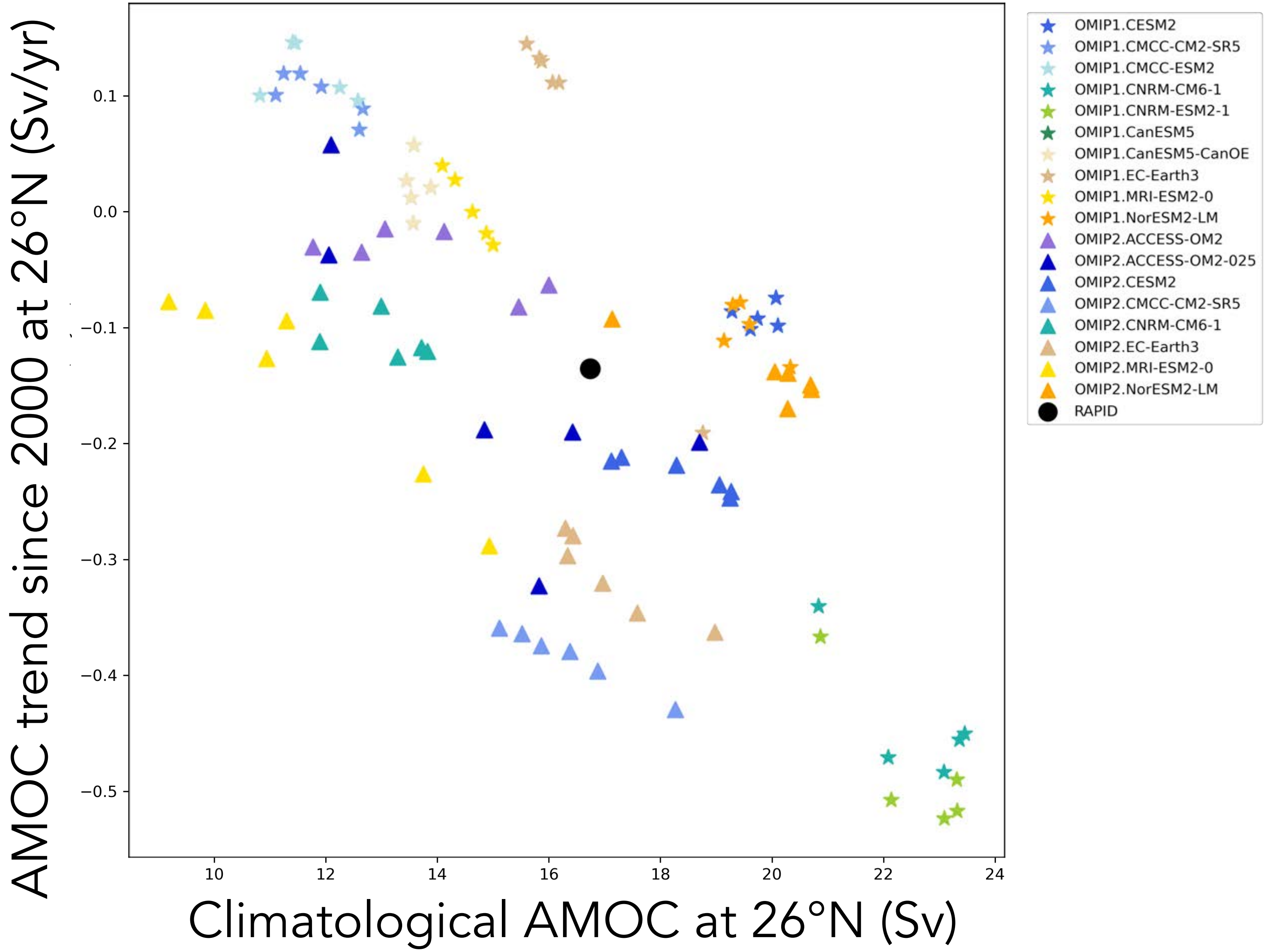




Stronger mean AMOC associated with greater variability



Models with stronger AMOC have greater decline since 2000



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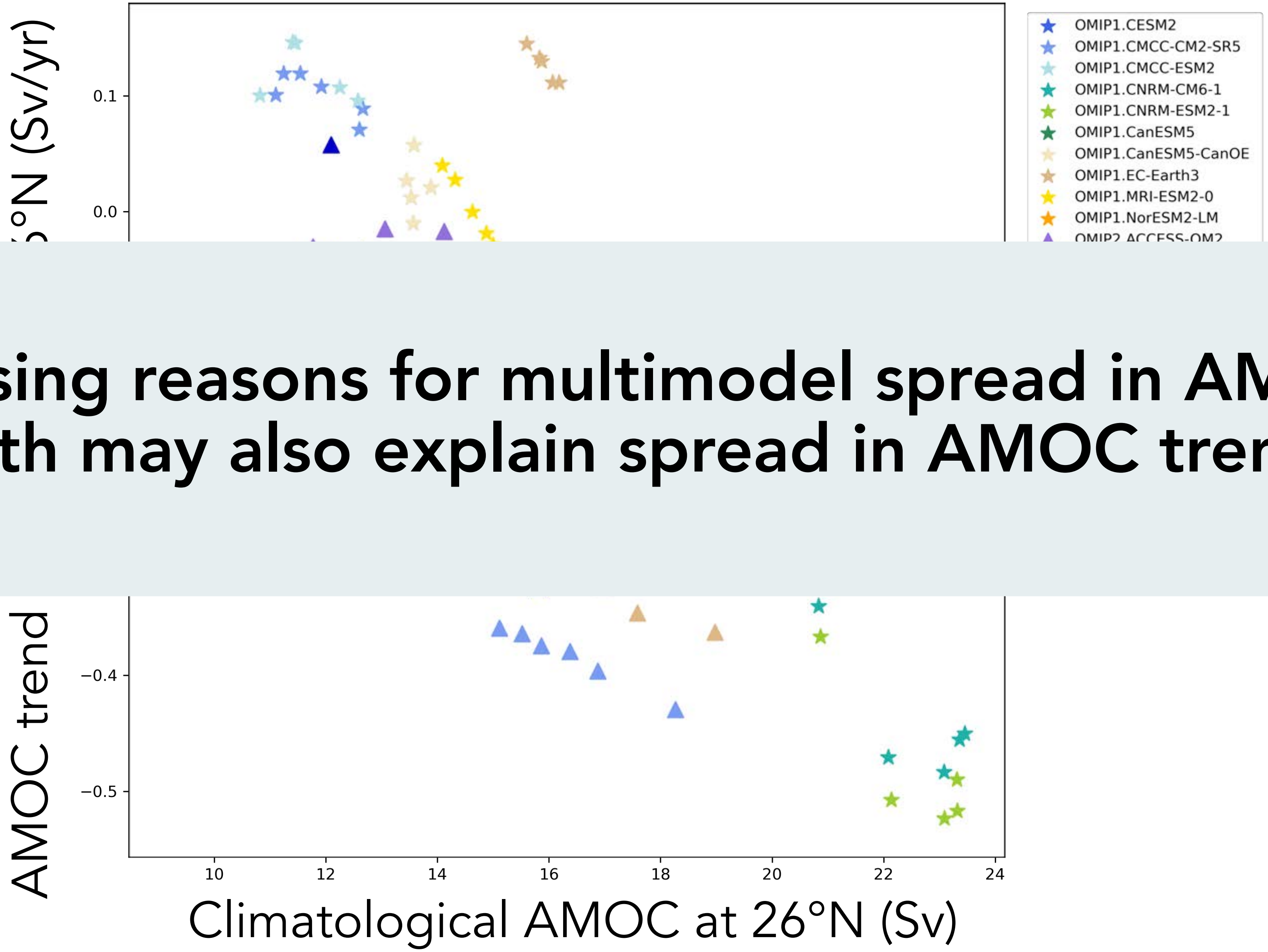
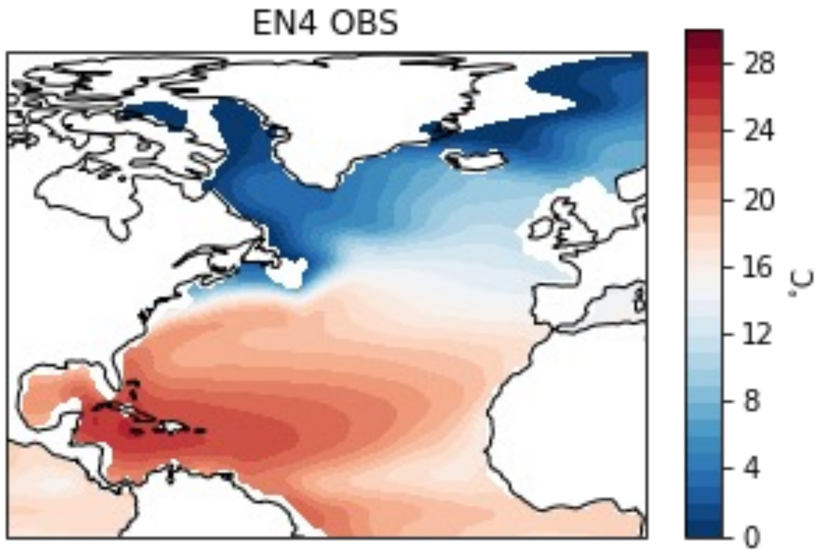


Diagnosing reasons for multimodel spread in AMOC strength may also explain spread in AMOC trends

OMIP simulations have large upper-ocean temperature biases in the Gulf Stream and North Atlantic Current regions



OMIP-1 upper-200m temperature biases

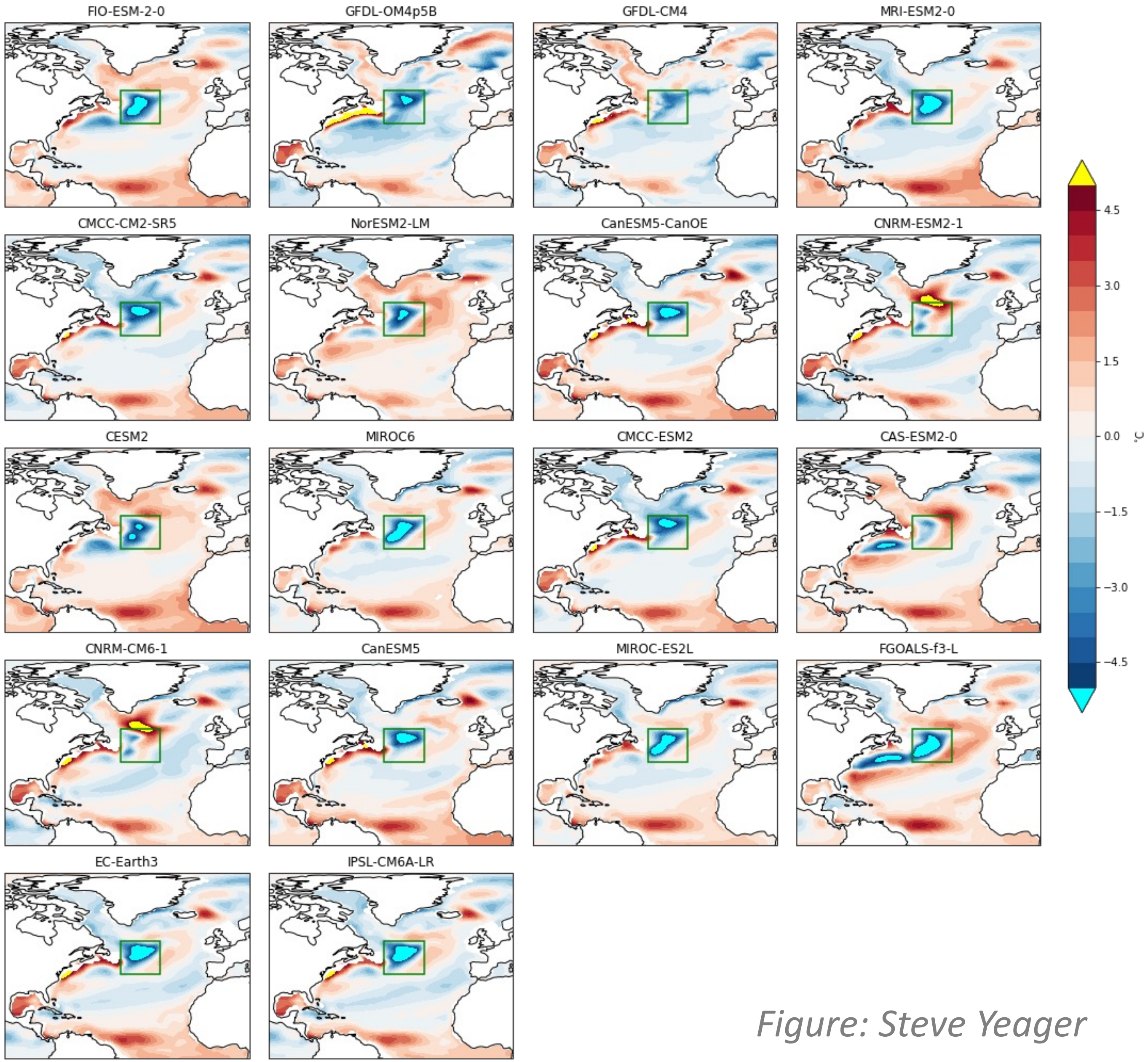
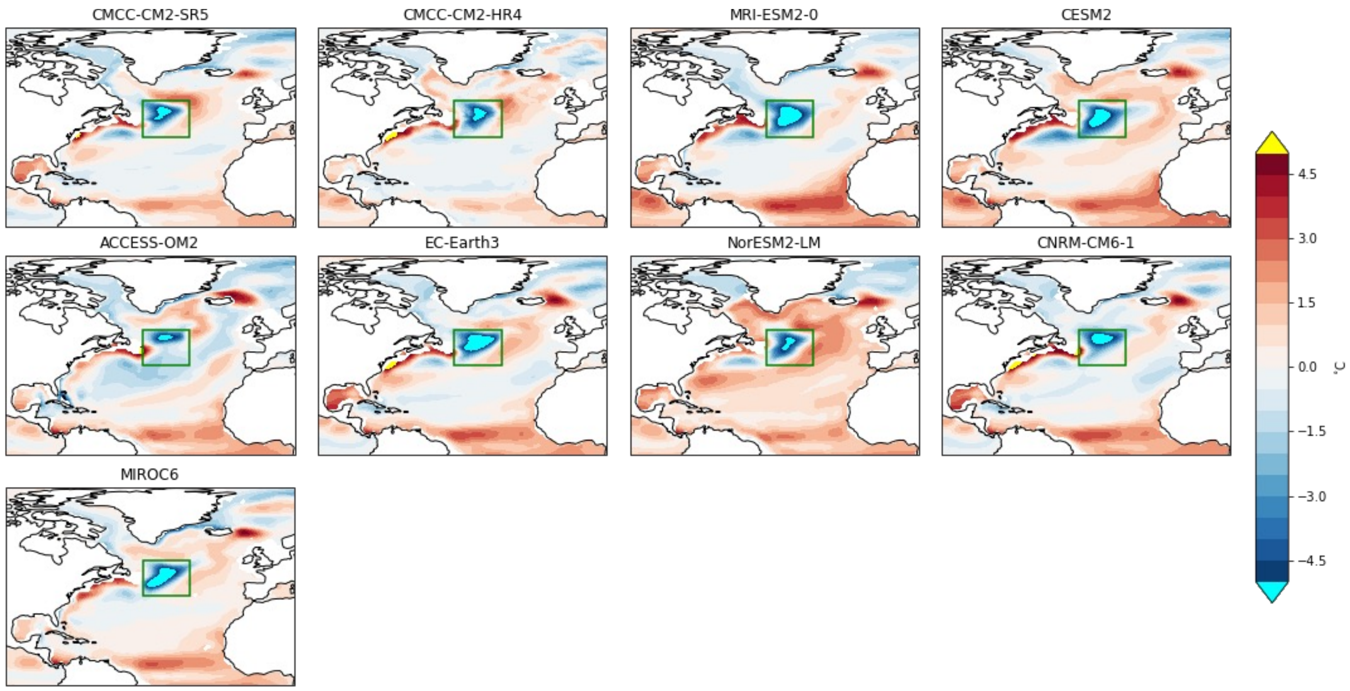


Figure: Steve Yeager

OMIP simulations have large upper-ocean temperature biases in the Gulf Stream and North Atlantic Current regions

OMIP-2 upper-200m temperature biases



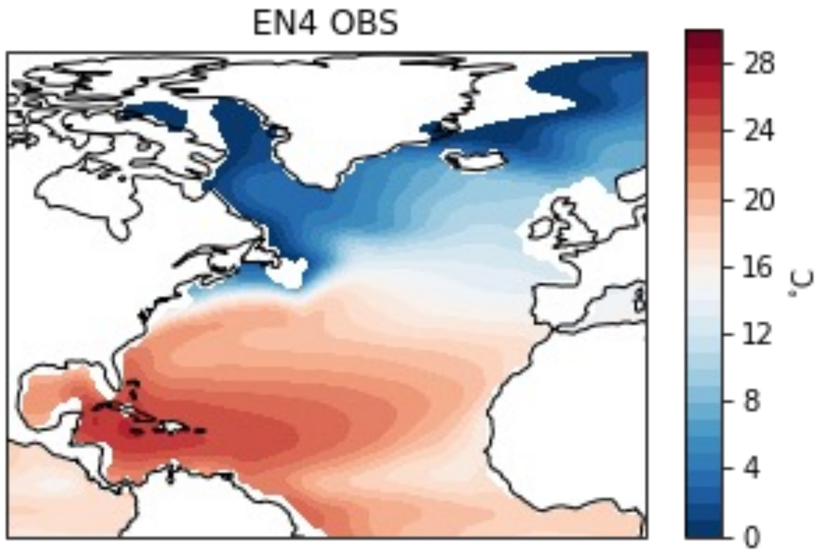
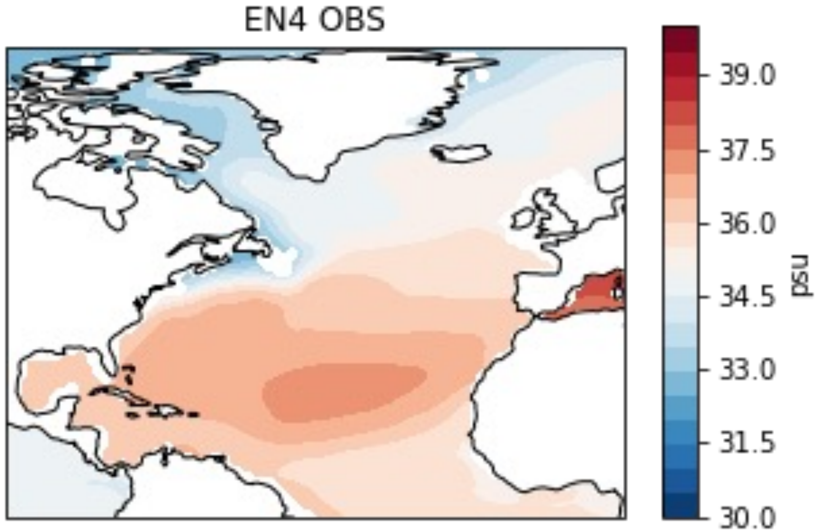


Figure: Steve Yeager

Large upper-ocean salinity biases also occur in the Gulf Stream and North Atlantic Current regions



OMIP-1 upper-200m salinity biases

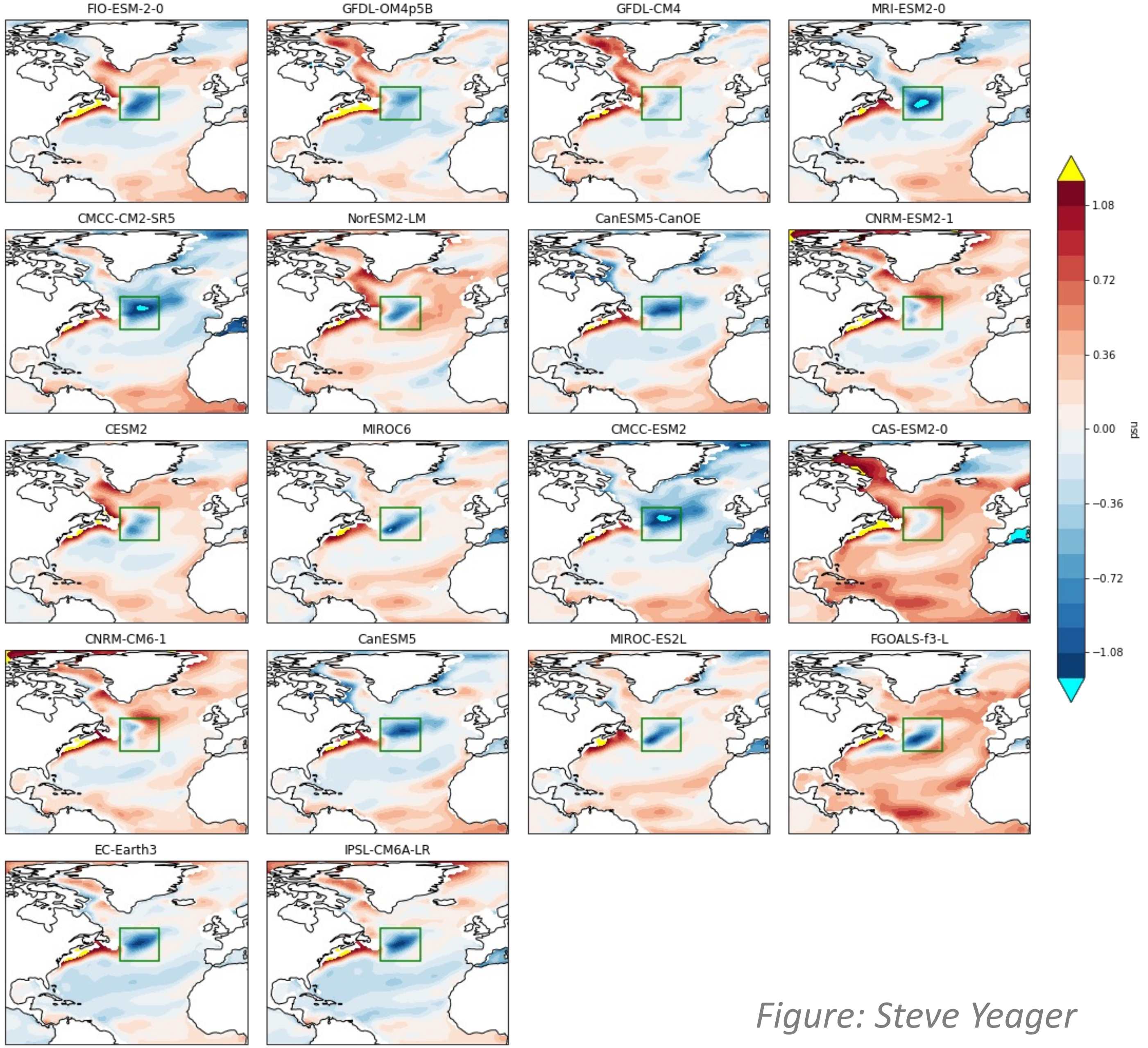
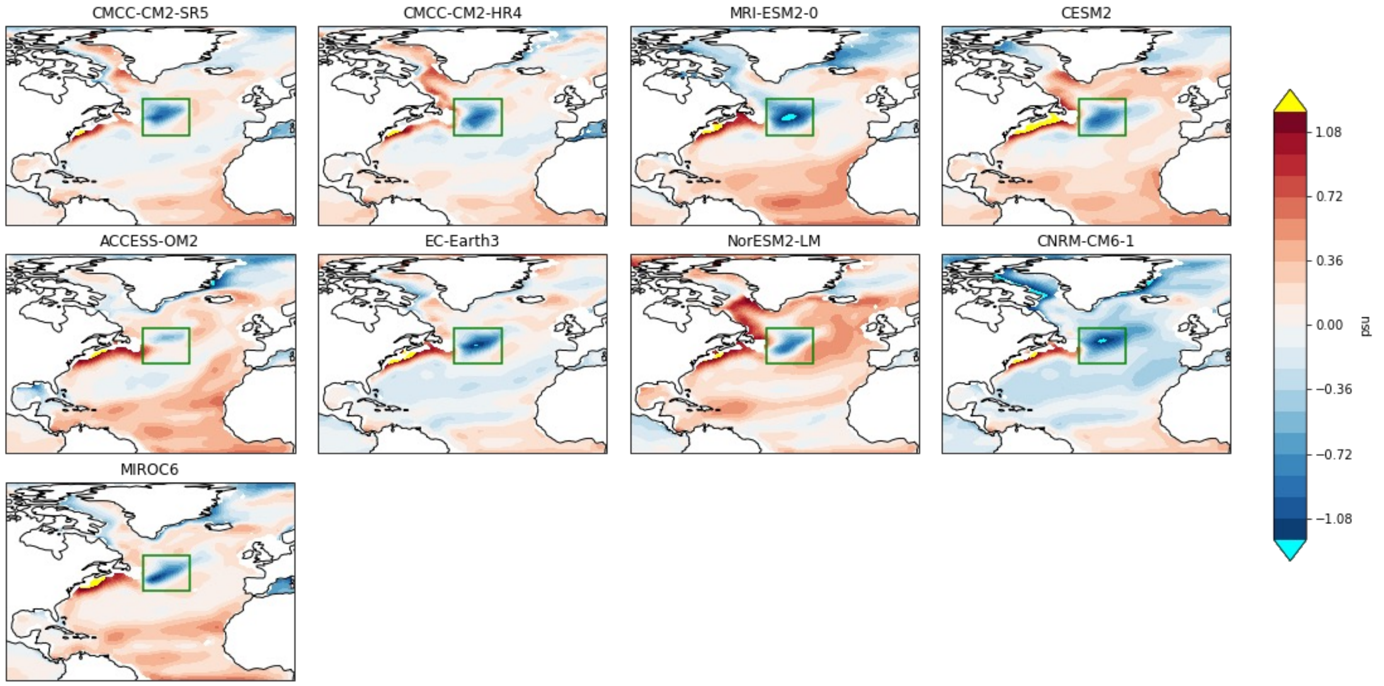


Figure: Steve Yeager

Large upper-ocean salinity biases also occur in the Gulf Stream and North Atlantic Current regions

OMIP-2 upper-200m salinity biases



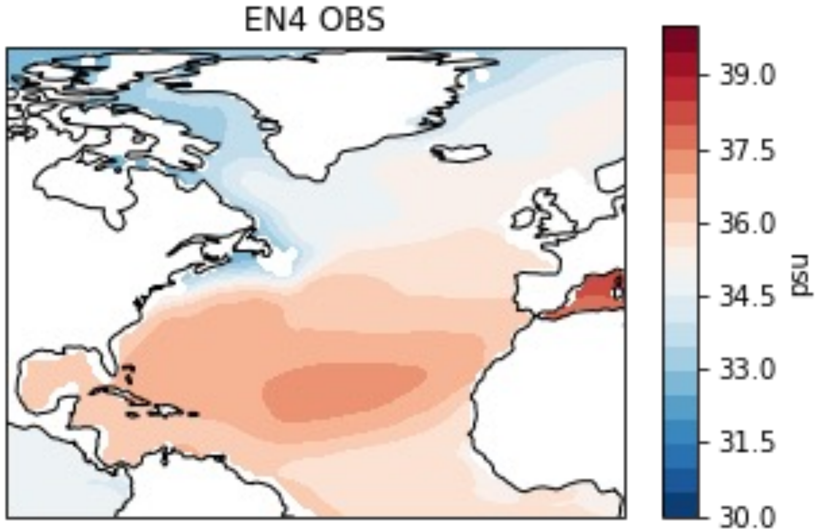
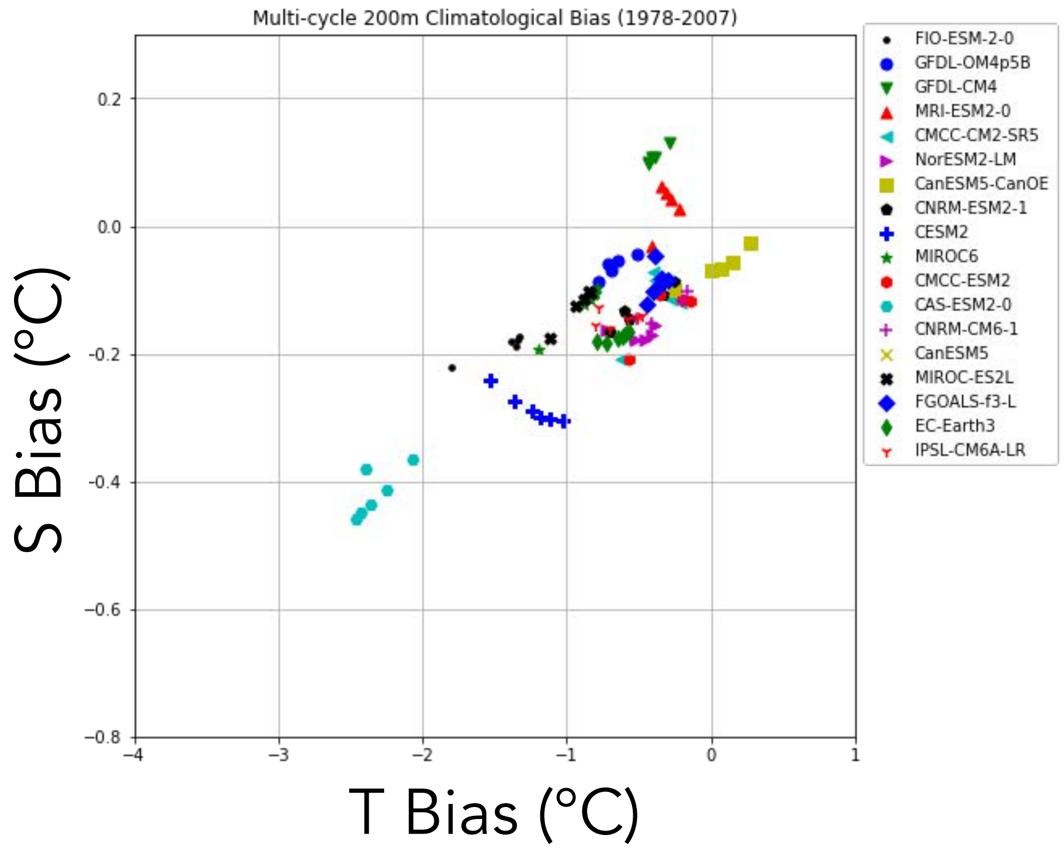


Figure: Steve Yeager

North Atlantic Current temperature and salinity bias strongly related in OMIP-1, less in OMIP-2.

OMIP-1



OMIP-2

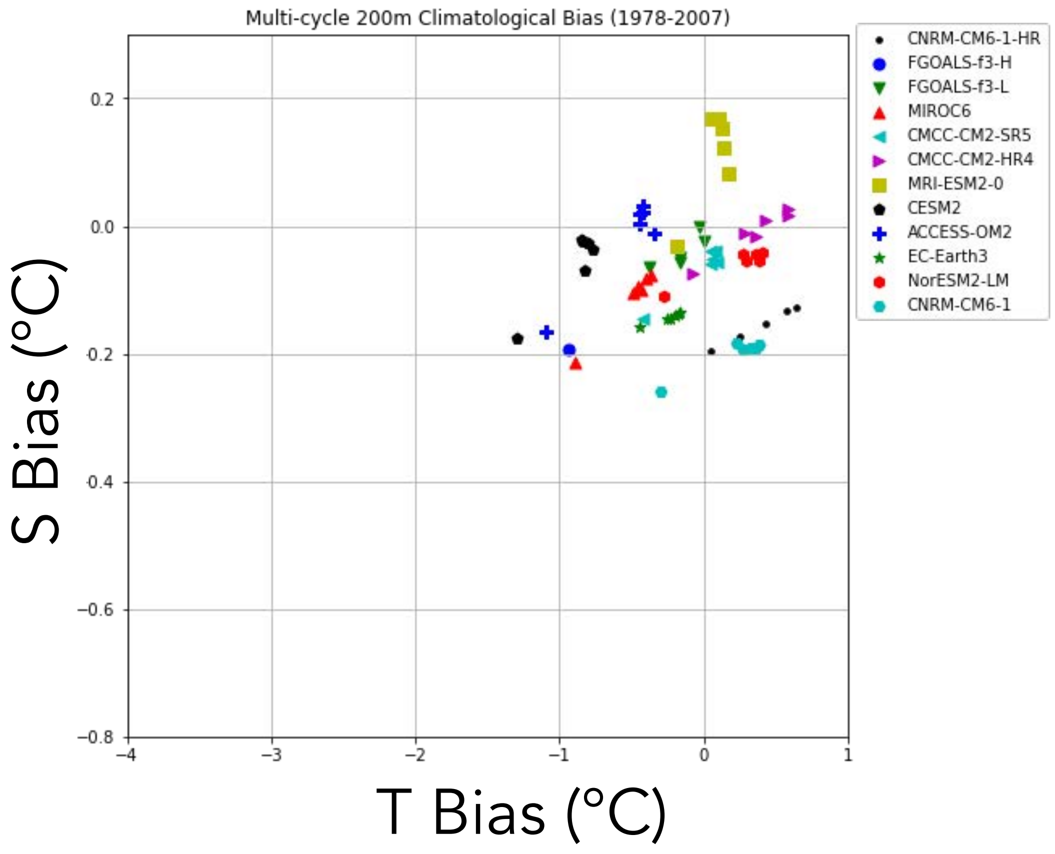
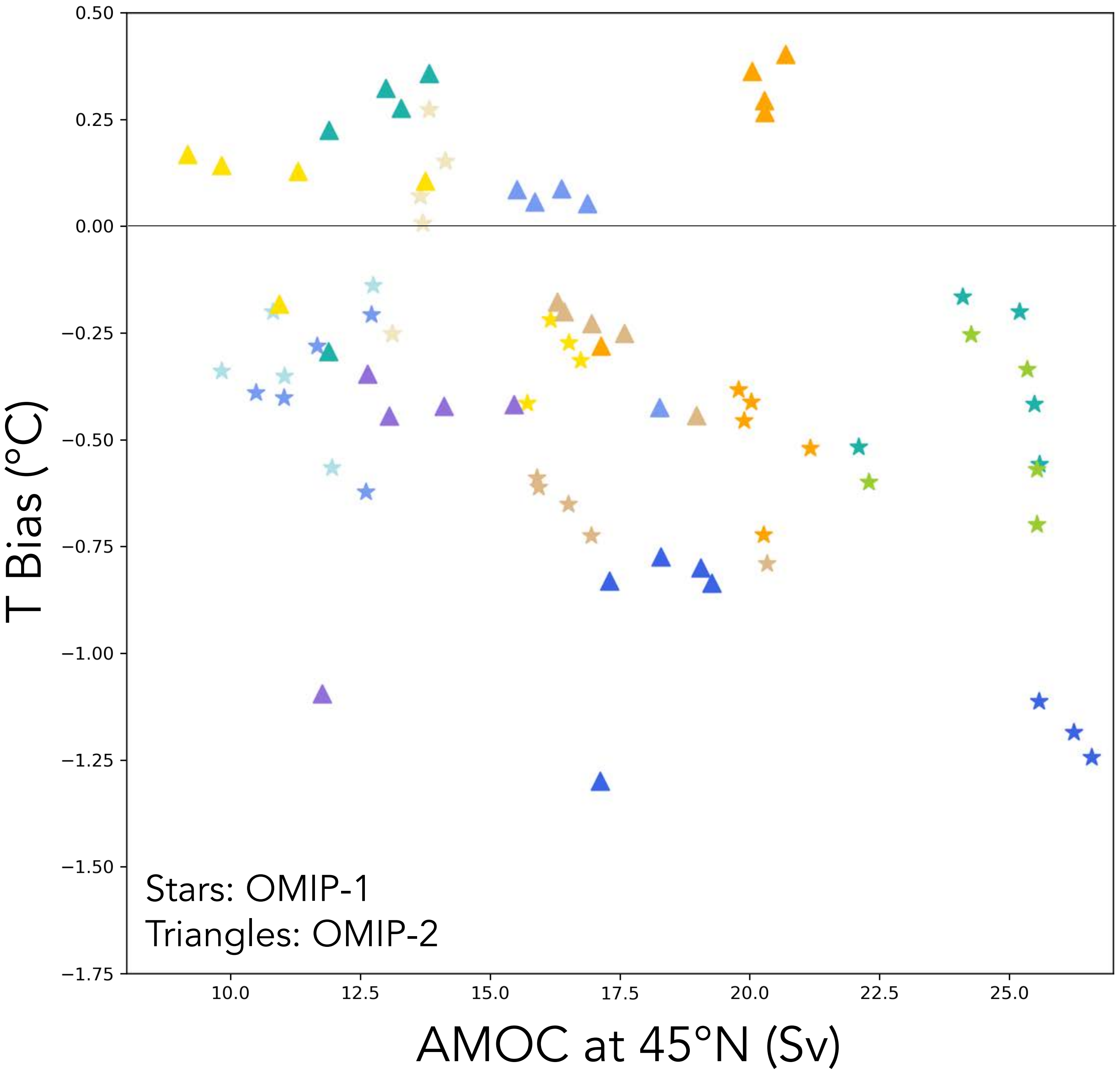
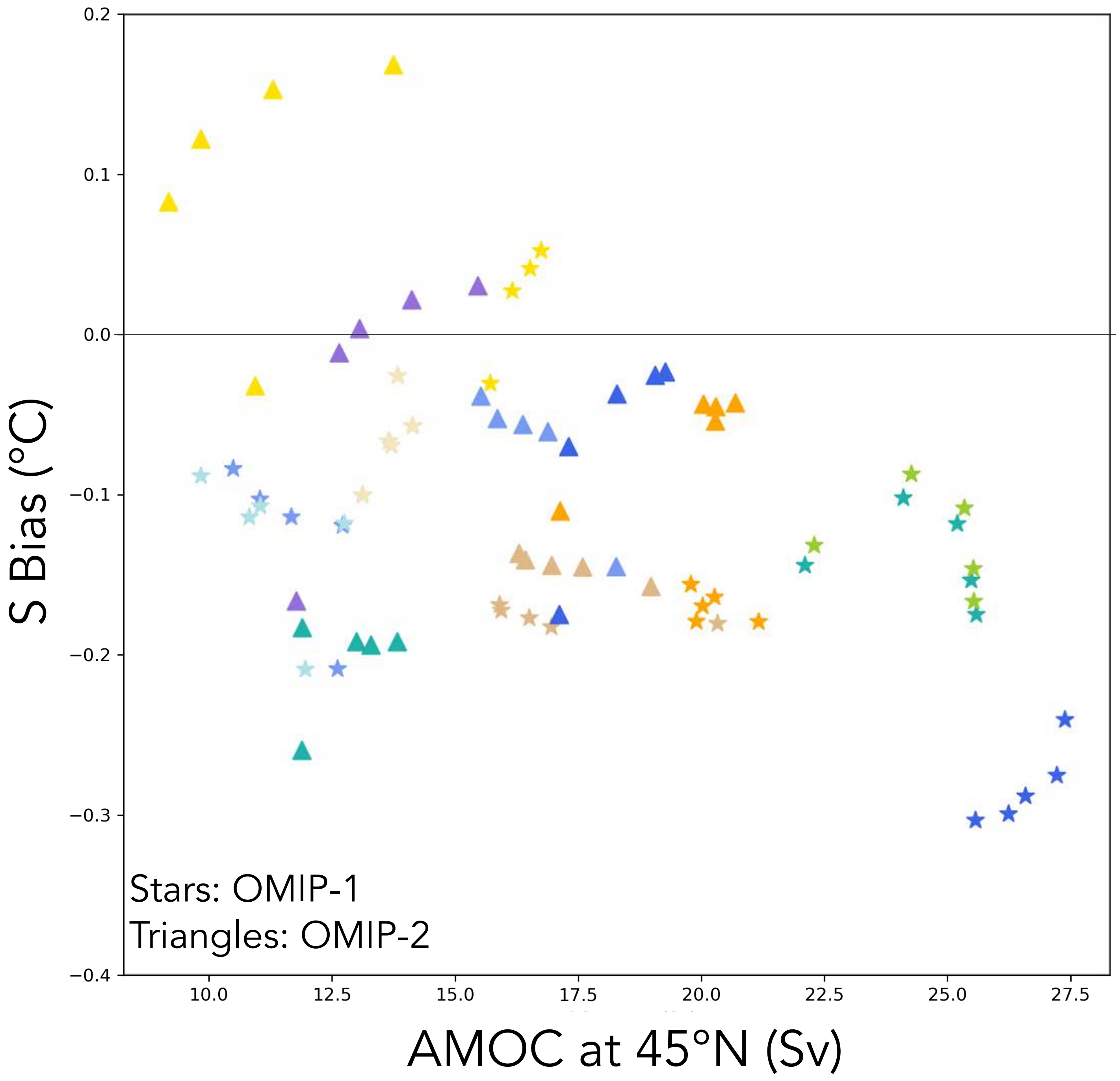


Figure: Steve Yeager

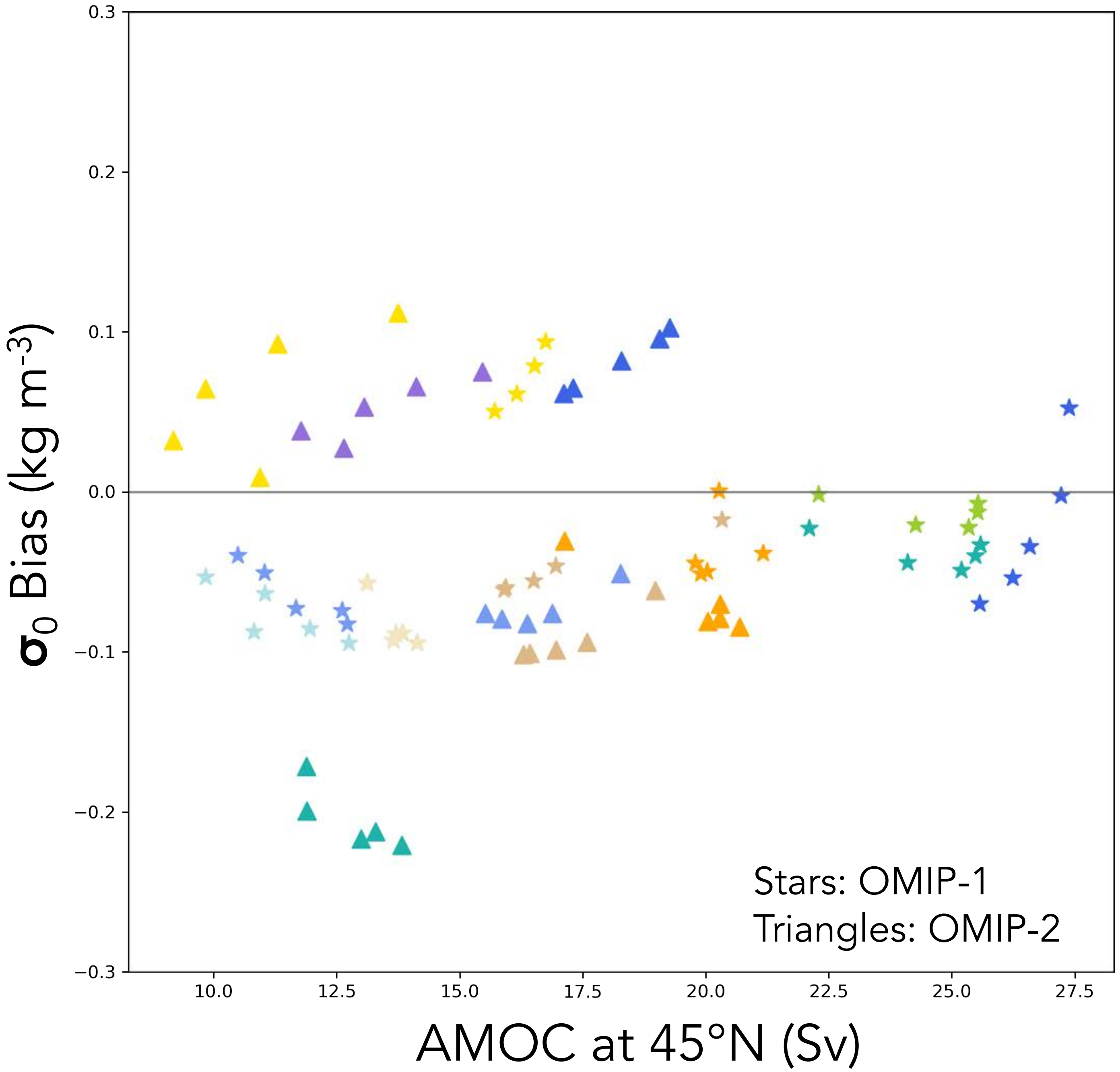
Stronger subpolar AMOC associated with larger North Atlantic Current cold bias



Stronger subpolar AMOC associated with larger North Atlantic Current fresh bias



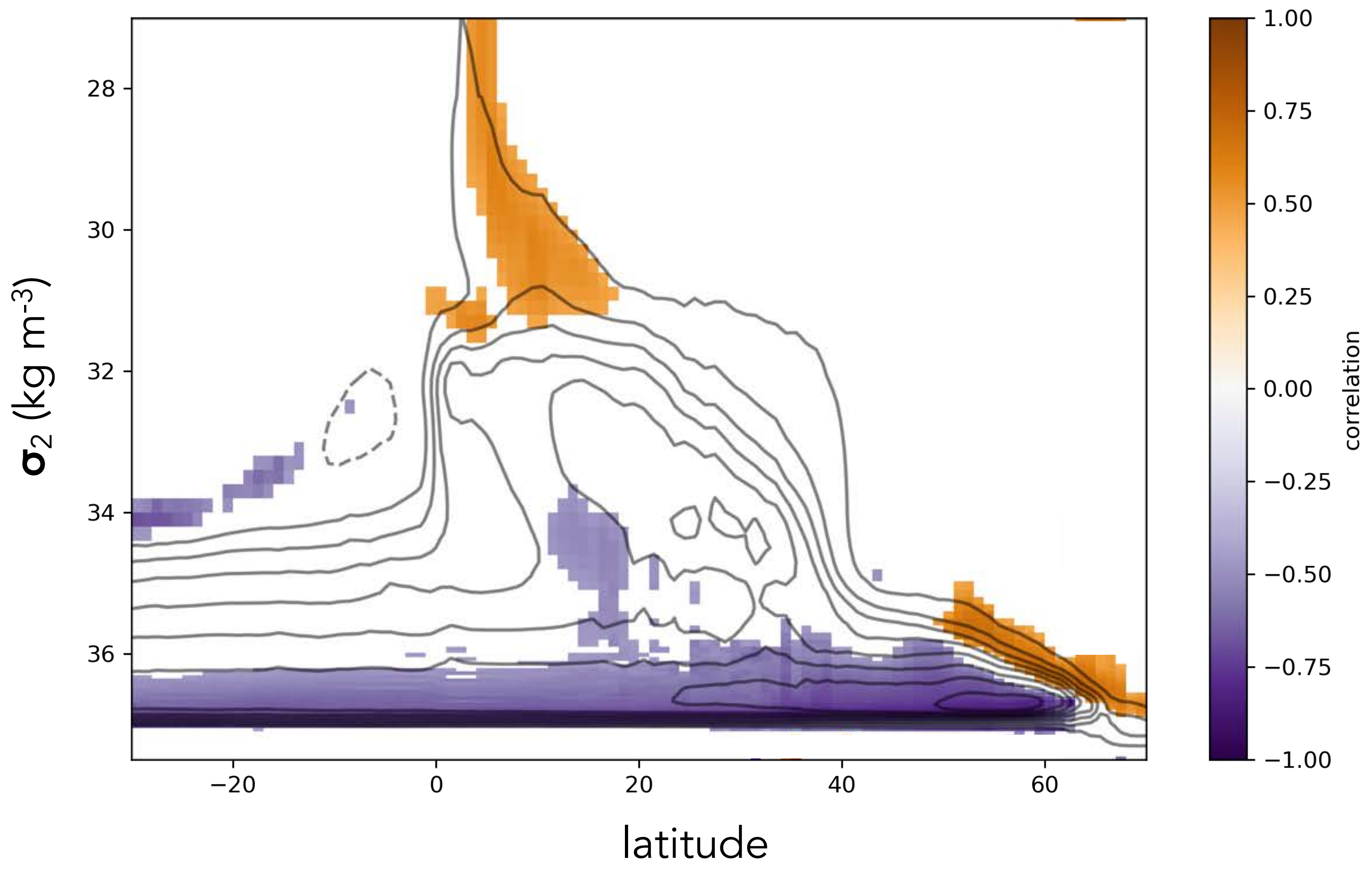
Yet, no clear relationship of AMOC with surface density bias in the North Atlantic Current region because of T and S compensation



OMIP simulations with reduced cold bias have:

1. North of 50°N, poleward upper-branch flow shifted to lighter water masses
2. Weaker deep overturning
3. Southward return flow shifted to lighter classes

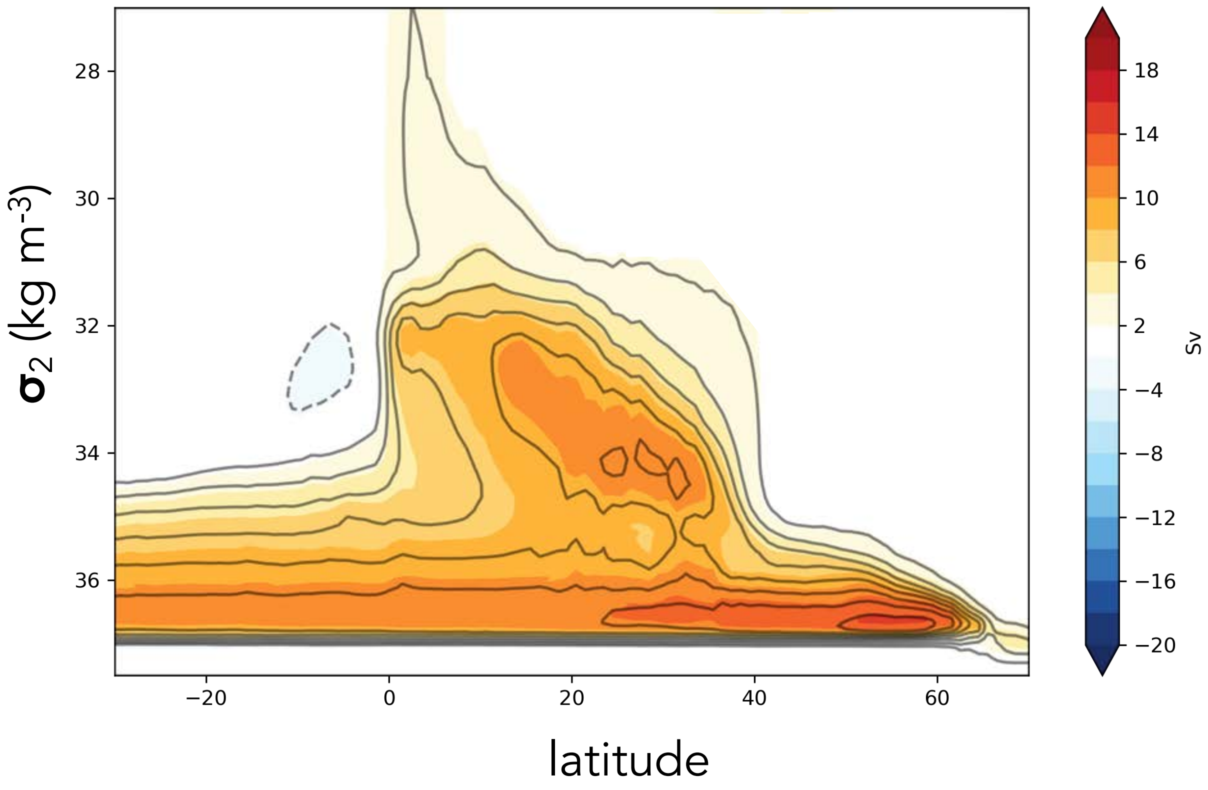
Cross-model correlation: AMOC streamfunction with T bias



Contours: Multimodel mean AMOC streamfunction
Shading: 95% significant cross-model correlation coefficient

OMIP simulations with reduced cold bias have poleward upper-branch flow at lighter classes, weaker overturning, and southward return flow at lighter classes.

Shading: Average AMOC in 3 models with weakest cold bias



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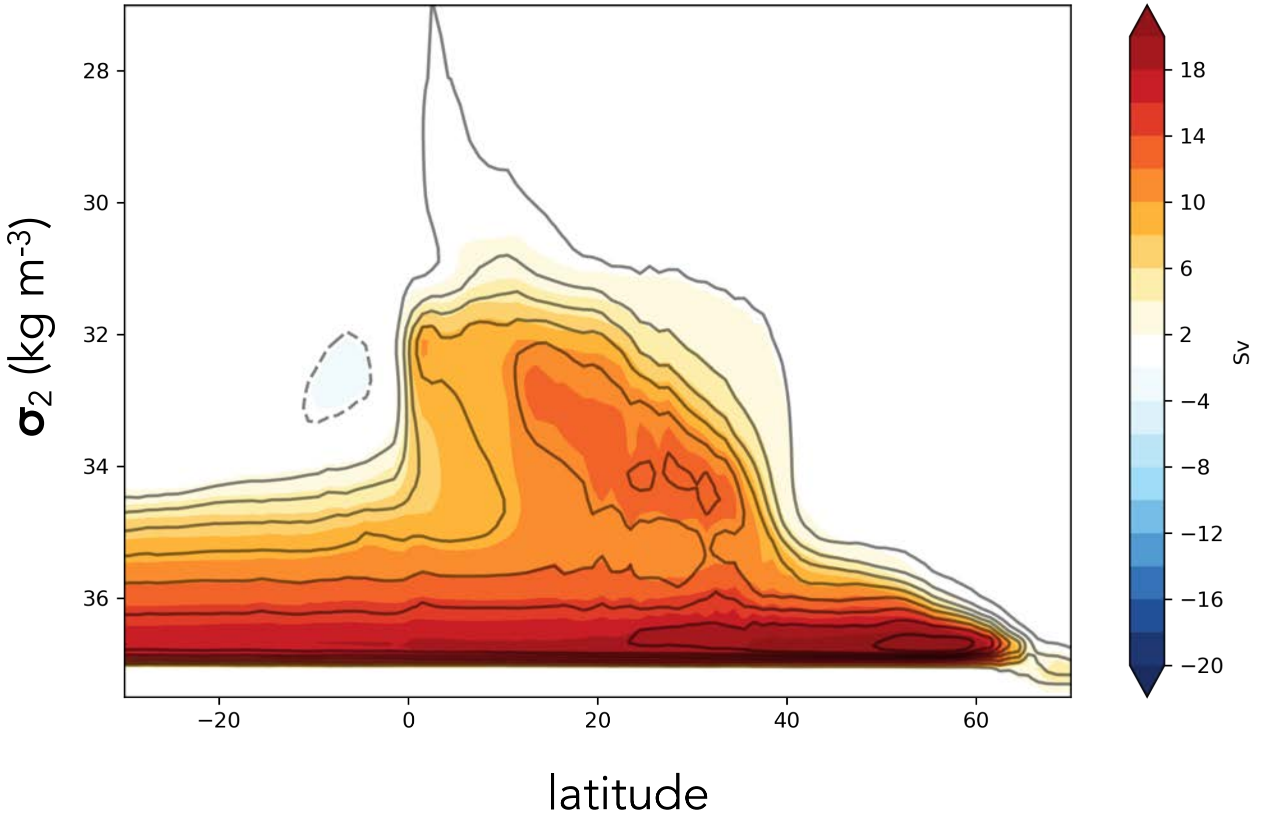
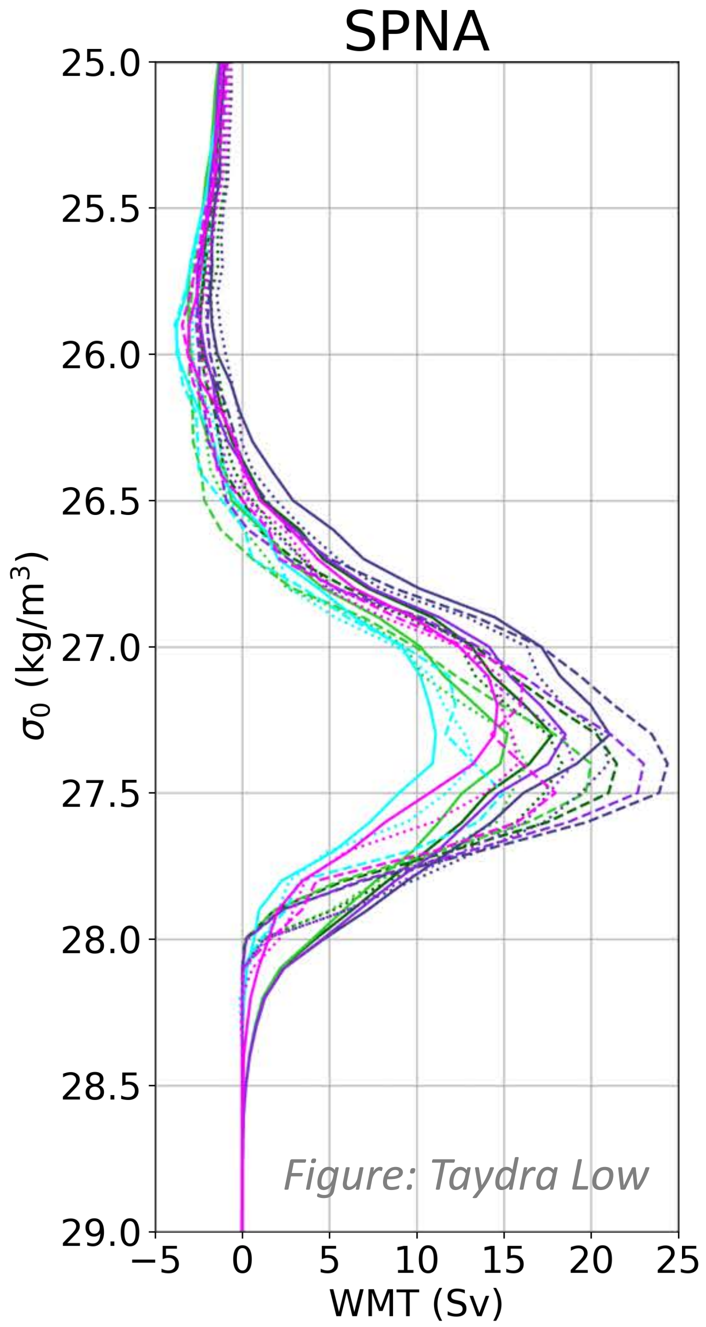


What's next: Water mass transformation to connect upper-ocean temperature and salinity to AMOC



Summary

- AMOC climatological strength linked to variability and trends since 2000 in OMIP simulations
- Temperature and salinity biases in North Atlantic Current region related to AMOC strength
- Reduced cold bias associated with shallowed, weaker AMOC upper cell throughout North Atlantic and near-surface subpolar transformation at lighter density classes